ANALYSIS OF THERMO-MECHANICAL STRESS EFFECTS ON CPV RECEIVER UNDER HIGH INTENSITY LIGHT CYCLES.

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ABSTRACT

After construction of the LYSS (Light cYcling Stressing Source) in early 2014, several CPV receivers, with and without secondary optical element (SOE) have been aged under fast transient illumination cycling,. The test plan for Madrid consisted of 50000 cycles. Receivers with poor heat spreaders showed low reliability but those with thicker metal layers passed the test well. The operation of LYSS along 8 months, after more than 250000 cycles, did not show any significant failure, except lamp reposition every 120 hours, in average. The equipment seems valid for unveiling weak receiver designs with respect to intensive illumination, in steady and transient modes.

1. INTRODUCTION

Receivers are a principal element of CPV modules because they hold the cell and the bypass diode; also carry out the electrical and thermal flows to their respective circuits. The semiconductor cell substrate is usually glued or soldered directly to plates which are made of different linear expansion coefficient materials. During normal steady state operation, the cell and the receiving plate are hot, thus withstanding permanent thermal-mechanical stress. However, along the system lifetime a high number of transient heating-cooling cycles will happen due to passing of clouds. Based on DNI series recorded in Madrid from 2011 to 2013, we forecast about 50.000 sudden and deep on/off illumination cycles along 30 years.[1]

In order to check the reliability of a CPV receiver vs. these hard illumination transient cycling, we have built an equipment (LYSS; from Light cYcling Stressing Source) able to perform that test on two cells at a maximum rate of 28.000 cycles per week. It is operating from January 2014 at IES-UPM for assessing about reliability of CPV receivers equipped with ·multi-junction cells. Fig. 1.

2. OBJECTIVES

The objectives of this paper is describing the performance of the LYSS machine found during the first year of operation as well as the results obtained on different receivers.

3. TRANSIENT MODE RELIABILITY TEST FOR CPV RECEIVERS

Our aim is to cycle and test as fast as possible, but assuring the receiver reaches steady state before the next light or dark step. Usual figures allow testing 2 cells every 30 a seconds [1]

Each cell under test can be in short-circuit or open circuit during cycling. Dark IV curve is recorded every N single cycles (N = 250 to 500) in order to check any degrading evolution or a fatal breakdown. The accurate measurement of the cell efficiency loss is carried out, later, in a solar simulator at controlled C-STC.

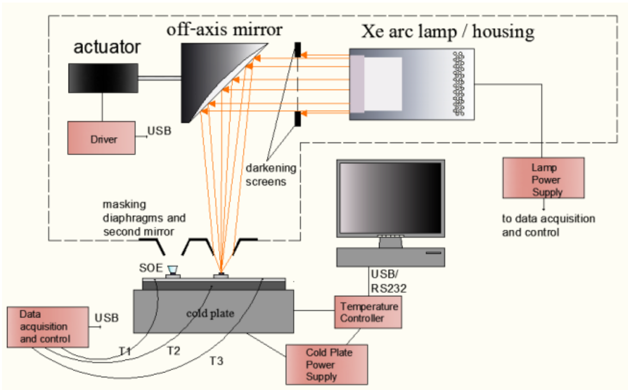

Fig. 1: Function blocks of LYSS machine prototype

Along the experiment, the receiver is thermally attached to a large base plate equipped with Peltier elements acting as heat sink. Base plate temperature can be programmed static or to slow cycling within the range 20 to 100 ºC. The user can select the base temperature, the durations of the light-dark cycles and the checking out period (COP). (For example: “T_{base}=60ºC, 10+10 s, N=500 cycles).

4 BASIC DESIGN OF LYSS MACHINE

The functional blocks of the device are shown in Fig.1. We use a continuous xenon-arc lamp, able to provide 250 W of collimated luminous power (400 to 2000 nm). The lamp beam is concentrated to a focal point by an off-axis parabolic dish mirror.

The receiver, with or without SOE, is located in this focal point. By means of a mechanical actuator the beam can be directed alternatively over two receivers, then doubling the testing rate. The limited collimation of the lamp beam asked to use an optical intensifier in order to reach up the level of 200 W/cm^2 and 70W/cm^2 on cells 0.1 and 1 cm^2 cell respectively.

4. EXPERIMENTS AND RESULTS

Several receivers, all mounting 10 mm^2 multi-junction solar cells, have been tested. Receivers type A consisted of an aluminium plate with cells and pads connected with fired conductive silver paste.

The group B consisted of DBC substrate (alumina plate with patterned copper in both sides) and the cell attached with conductive silver epoxy. Group C consisted of DBC, (like Group B), but now a truncated glass pyramid SOE is glued with transparent silicone to the cell surface. Group D is like group C, but the spreading copper layers are not present. Fig.2.

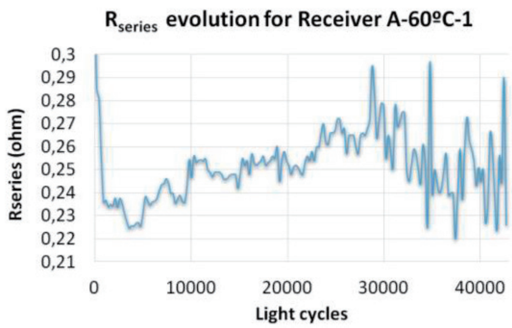

Fig. 3: Very small variation of R_{series} for sample A-60C-1. It passed the test.

Four type A receivers have been cycled at 100W/cm^2. Two at 60ºC and the others at 80ºC. The series resistance was extracted from the dark IV curve, every 240 cycles. Cell A-60C-2 failed at 30000 cycles. See Fig 4.

Cell A-80ºC-1failed at 6000 cycles.

The other two type A receivers withstand 42000 cycles with no sensible variation of series resistance. See Fig.2.

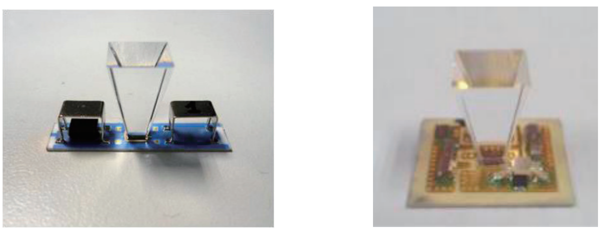

Fig. 2. Receiver type D, alumina substrate without metal spreading (left). Receiver type C: DBC substrate (right

The plots of Fig. 3 and 4 show that the sudden increase of R_{series} is mostly associated with a significant degradation of the cell efficiency, which is measured at 80W.cm^{-2} before and after the aging test

The test on group D led to immediate failure of the receiver. It reached over 250ºC and caused the lack of mechanical and optical coupling of SOE. These last results have shown that LYSS machine is also adequate for continuous thermal test in the range 100W/cm2,

The experiments with Group B did not give any negative surprise, because all samples withstand the test without degradation. Finally, in group C, a sudden increase of series resistance happened at 18000 cycles, 100W/cm^2.

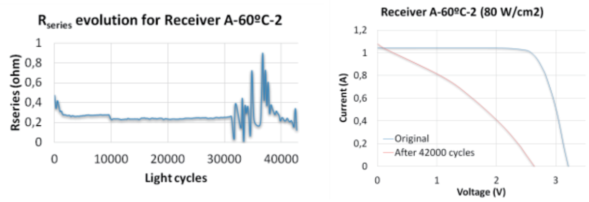

Fig.4. Correspondence between increase of R_{series} and cell degradation for sample A-60-2

It did not affect the cell efficiency but puts some warning about possible mechanical damage of silicone expansion to cell wires or to SOE optical coupling The plot of figure 5 shows the records for group C samples.

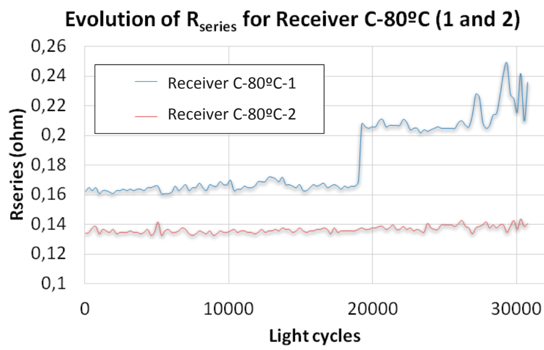

Fig. 5. s Evolution of R_{series} for samples type C-80C.

5. CONCLUSIONS

The continuous operation of the LYSS machine at high levels of irradiance and more than 250000 cycles along months is proven. Relationship between receiver degradation and series resistance increase seems consistent, although the small number of experiments carried out. The inadequacy of aluminum receiver substrate has been proven with this test. The good performance of DBC substrates is confirmed for transient cycling mode. The test has shown some weakness of SOE attachment to cell. However the small number of tests, due to the long testing time, is not yet statistically consistent, but is pointing some sources of problems.. The equipment can be also used in continuous mode for checking the reliability of new receivers indoor in short time.

6 REFERENCES

[1] V. Pérez et al. *"Induced Thermo-Mechanical Stress in CPV Receivers with Cycled High Intensity Light"* AIP Conf. Proc.1616, 254-258 (2014)doi:10.1063/1.4897073

7. ACKOWLEDGEMENTS

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